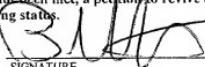


FORM PTO-1390 (REV. 11-2000)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY'S DOCKET NUMBER
				<b>A01204US (98148.18)</b>
		U.S. APPLICATION NO. (If known, see 37 CFR 1.5)		
		<b>09/913902</b>		
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		INTERNATIONAL APPLICATION NO.		PRIORITY DATE CLAIMED
INTERNATIONAL APPLICATION NO. <b>PCT/GB00/00521</b>		INTERNATIONAL FILING DATE <b>17 February 2000 (17.02.00)</b>		PRIORITY DATE CLAIMED <b>17 February 1999 (17.02.99)</b>
TITLE OF INVENTION "ROTATING SURFACE OF REVOLUTION REACTOR WITH FEED AND COLLECTION MECHANISMS"				
APPLICANT(S) FOR DO/EO/US <b>RAMSHAW, Colin; JACHUCK, Roshan, Jeet, Gee</b>				
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:				
<ol style="list-style-type: none"> <li><input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li><input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li><input type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.</li> <li><input type="checkbox"/> The US has been elected by the expiration of 19 months from the priority date (Article 31).</li> <li><input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))             <ol style="list-style-type: none"> <li><input type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau).</li> <li><input checked="" type="checkbox"/> has been communicated by the International Bureau.</li> <li><input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</li> </ol> </li> <li><input type="checkbox"/> An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).             <ol style="list-style-type: none"> <li><input type="checkbox"/> is attached hereto.</li> <li><input type="checkbox"/> has been previously submitted under 35 U.S.C. 154(d)(4).</li> </ol> </li> <li><input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))             <ol style="list-style-type: none"> <li><input checked="" type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau).</li> <li><input checked="" type="checkbox"/> have been communicated by the International Bureau.</li> <li><input type="checkbox"/> have not been made, however, the time limit for making such amendments has NOT expired</li> <li><input type="checkbox"/> have not been made and will not be made.</li> </ol> </li> <li><input type="checkbox"/> An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</li> <li><input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).</li> <li><input type="checkbox"/> An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</li> </ol>				
Items 11 to 20 below concern document(s) or information included:				
<ol style="list-style-type: none"> <li><input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</li> <li><input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</li> <li><input type="checkbox"/> A <b>FIRST</b> preliminary amendment.</li> <li><input type="checkbox"/> A <b>SECOND</b> or <b>SUBSEQUENT</b> preliminary amendment.</li> <li><input type="checkbox"/> A substitute specification.</li> <li><input type="checkbox"/> A change of power of attorney and/or address letter.</li> <li><input type="checkbox"/> A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1821 - 1825.</li> <li><input checked="" type="checkbox"/> A second copy of the published international application under 35 U.S.C. 154(d)(4).</li> <li><input type="checkbox"/> A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).</li> <li><input type="checkbox"/> Other items or information:</li> </ol>				

U.S. APPLICATION NO (If known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO <b>PCT/GB00/00521</b>	ATTORNEY'S DOCKET NUMBER <b>A01204US (98148.18)</b>
21. <input type="checkbox"/> The following fees are submitted:		CALCULATIONS PTO USE ONLY
<b>BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):</b>		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO . . . . . <b>\$1000.00</b>		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO . . . . . <b>\$860.00</b>		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO . . . . . <b>\$710.00</b>		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) . . . . . <b>\$690.00</b>		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) . . . . . <b>\$100.00</b>		
<b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b> <b>\$ 1,000</b>		
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input checked="" type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)). <b>\$ 130</b>		
CLAIMS	NUMBER FILED	NUMBER EXTRA
Total claims	- 20 =	x \$18.00
Independent claims	- 3 =	x \$80.00
<b>MULTIPLE DEPENDENT CLAIM(S) (if applicable)</b> + \$270.00		
<b>TOTAL OF ABOVE CALCULATIONS =</b> <b>\$ 1,130</b>		
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2. + <b>\$ 565</b>		
<b>SUBTOTAL =</b> <b>\$ 565</b>		
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)). <b>\$</b>		
<b>TOTAL NATIONAL FEE =</b> <b>\$ 565</b>		
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) \$40.00 per property + <b>\$</b>		
<b>TOTAL FEES ENCLOSED =</b> <b>\$ 565</b>		
		Amount to be refunded: <b>\$</b>
		charged: <b>\$</b>
<p>a. <input checked="" type="checkbox"/> A check in the amount of <b>\$ 565</b> to cover the above fees is enclosed.</p> <p>b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.</p> <p>c. <input type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. _____. A duplicate copy of this sheet is enclosed.</p> <p>d. <input type="checkbox"/> Fees are to be charged to a credit card. WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.</p>		
NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.		
SEND ALL CORRESPONDENCE TO. <b>Seth M. Nehrbass</b>		
<b>GARVEY, SMITH, NEHRBASS &amp; DOODY, L.L.C.</b>		
3838 N. CAUSEWAY BLVD., STE 3290		
METAIRIE, LA 70002		
US		
PTO Customer Number 22920		
 <b>SIGNATURE</b> <b>BRETT A. NORTH</b> NAME _____ <b>42,040</b> REGISTRATION NUMBER _____		

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

APPLICANTS: RAMSHAW, Colin and  
JACHUCK, Roshan, Jeet, Jee

**09/913902**

ASSIGNEE: Protensive Limited (A UK Company)

U.S. APPLICATION NO.: 09/913,902

INTERNATIONAL APPL. NO.: PCT/GB00/00521 I.A. FILING DATE: 02-17-2000

FOR: "PROCESS FOR THE CONVERSION OF A FLUID PHASE SUBSTRATE BY DYNAMIC HETEROGENEOUS CONTACT WITH AN AGENT"

ATTORNEY DOCKET NO.: A01204US (98148.18)

\* \* \* \* \*

**PRELIMINARY AMENDMENT AND RESPONSE TO NOTICE TO FILE MISSING PARTS**

Commissioner of Patents  
and Trademarks  
Washington, D.C. 20231

Sir:

This is an Amendment and Response to the Notice mailed from the U.S. Patent Office on October 19, 2001 in the above-referenced application. A deadline to respond was set to expire two months from the date of the Notice, making a response due by December 19, 2001.

**AMENDMENT**

Please amend the application as follows:

**IN THE CLAIMS:**

Please amend the claims to read as follows:

--1. (Amended) A reactor apparatus including a support element adapted to be rotatable about an axis, the support element having a surface, feed means for supplying at least one reactant to the surface of the support element and collector means for collecting product from the surface of the support element, characterised in that the surface includes an undercut trough into which the at

least one reactant is directly supplied by the feed means when the reactor apparatus is in use, and in that, upon rotation of the support element, the at least one reactant forms a generally annular film within the at least one undercut trough and passes therefrom across the surface of the support element.

2.(Amended) A reactor as claimed in claim 1, wherein the axis is substantially parallel to a direction of action of terrestrial gravity.

3.(Amended) A reactor as claimed in claim 1, wherein the axis is inclined with respect to a direction of action of terrestrial gravity.

4.(Amended) A reactor as claimed in claim 1, wherein the axis is substantially perpendicular to a direction of action of terrestrial gravity.

5.(Amended) A reactor as claimed in claim 1, wherein the trough is centrally located in the region of the axis.

6.(Amended) A reactor as claimed in claim 1, wherein the trough is in the form of an annulus.

7.(Amended) A reactor as claimed in claim 1, wherein the trough is centred about the axis.

8.(Amended) A reactor as claimed in claim 1, wherein the trough is not centred on the axis.

9.(Amended) A reactor as claimed in claim 1, wherein a plurality of troughs is provided in the surface.

10.(Amended) A reactor as claimed in claim 9, wherein each trough has associated with it a feed means.

11.(Amended) A reactor as claimed in claim 1, wherein the trough is provided with a matrix which serves to assist reactant in the trough to rotate with the support element when this is rotated.

12.(Amended) A reactor as claimed in claim 11, wherein the matrix comprises a fibrous mesh.

14.(Amended) A reactor as claimed in claim 12, wherein the fibrous mesh includes a catalytic material.

15.(Amended) A reactor as claimed in claim 1, wherein the collector means includes a receptacle in the form of a bowl or trough at least partially surrounding the support element.

16.(Amended) A reactor as claimed in claim 1, wherein the collector means includes a deflector positioned about a periphery of the support element, against which product is thrown from an edge region of the surface when the support element is rotating at an appropriate speed.

17.(Amended) A reactor as claimed in claim 1, wherein the collector means is coated or otherwise provided with a catalytic material.

18.(Amended) A reactor as claimed in claim 1, wherein the collector means includes means for heating or cooling product in the collector means to a predetermined temperature.

19.(Amended) A reactor as claimed in claim 1, wherein the collector means is provided with feed means for adding a reactant to product collected therein.

20.(Amended) A reactor as claimed in claim 1, wherein the collector means comprises a wall disposed on a periphery of the support element and extending from the surface.

21.(Amended) A reactor as claimed in claim 20, wherein the collector means further comprises a pitot tube which extends close to the surface in the region of the wall and which serves to remove product from this region when the support element is rotated.

22.(Amended) A reactor as claimed in claim 1, wherein the collector means is adapted at least partially to recycle collected product to the trough as feed reactant.

23.(Amended) A reactor as claimed in claim 1, wherein the trough is coated or otherwise provided with a catalytic material.

24.(Amended) A reactor as claimed in claim 1, including a plurality of support elements.

25.(Amended) A reactor as claimed in claim 24, wherein the plurality of support elements is mounted on a single axis of rotation.

26.(Amended) A reactor as claimed in claim 24, wherein the plurality of support elements is mounted on a plurality of axes of rotation.

27.(Amended) A reactor as claimed in claim 24, wherein product collected from a first support member is used as feed for a second support member.

28.(Amended) A reactor as claimed in claim 24, wherein feed means connected in parallel are used to supply reactant to each support element and in which collector means connected in parallel are used to collect product from each support element.

29.(Amended) A reactor as claimed in claim 27, wherein a processing unit is provided

between the collector means of the first support member and the feed means of the second support member.

30.(Amended) A reactor as claimed in claim 29, wherein the processing unit is a pump, an extruder, a heater or a heat exchanger.

31.(Amended) A reactor as claimed in claim 1, wherein the feed means includes means for applying electromagnetic radiation or energy to the reactant.

32.(Amended) A reactor as claimed in claim 1, further including means for applying vibration to the support member.

33.(Amended) A reactor as claimed in claim 1, wherein there is further provided a rotary impeller or fan mounted close to the surface and operable to generate a gaseous flow from a periphery of the surface towards a central region thereof, this flow being counter-current to a flow of reactant on the surface. --

#### REMARKS

The claims have been amended to eliminate multiple dependencies. Two sets of claims are included, one set showing the changes made in this response (attached) and one clean set (set out above). No new matter has been added to the application.

A declaration has been enclosed. Additional claims fees of \$117.00 have been included, however, no fee for multiple dependent claim has been included as the multiple dependencies have been removed by preliminary amendment.

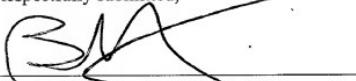
Applicant respectfully submits that the application is in condition for allowance. A Notice of Allowance is hereby respectfully requested.

Should the Examiner feel that a telephone conference would advance the prosecution of this application, he is encouraged to contact the undersigned at the telephone number listed below.

Applicant respectfully petitions the Commissioner for any extension of time necessary to render this paper timely.

Please charge any fees due or credit any overpayment to Deposit Account No. 50-0694.

Respectfully submitted,



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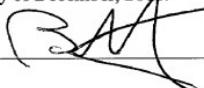
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CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service as First Class Mail in an envelope addressed to: Commissioner of Patents and Trademarks, Washington, D.C. 20231, on this 12 day of December, 2001.



P:\Brett\98148 18-PreAmend+Res.wpd

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

APPLICANTS:            RAMSHAW, Colin and  
                          JACHUCK, Roshan, Jeet, Gee

ASSIGNEE:            Protensive Limited (A UK Company)

U.S. APPLICATION NO.: 09/913,902

INTERNATIONAL APPL. NO.: PCT/GB00/00521     I.A. FILING DATE: 02-17-2000

FOR:            "PROCESS FOR THE CONVERSION OF A FLUID PHASE SUBSTRATE BY  
                  DYNAMIC HETEROGENEOUS CONTACT WITH AN AGENT"

ATTORNEY DOCKET NO.: A01204US (98148.18)

\* \* \* \* \*

**Copy of Amendments Showing Changes**

The application has been amended in the foregoing amendment to read as follows (added matter is underlined and omitted matter is in brackets). To facilitate prosecution all claims have been included, even those not amended:

1.(Amended) A reactor apparatus including a support element [(3)] adapted to be rotatable about an axis [(6)], the support element [(3)] having a surface [(5)], feed means [(4)] for supplying at least one reactant [(15)] to the surface [(5)] of the support element [(3)] and collector means for collecting product [(19)] from the surface [(5)] of the support element [(3)], characterised in that the surface [(5)] includes an undercut trough [(13,14)] into which the at least one reactant [(15)] is directly supplied by the feed means [(4)] when the reactor apparatus is in use, and in that, upon rotation of the support element [(3)], the at least one reactant [(15)] forms a generally annular film [(16)] within the at least one undercut trough [(13,14)] and passes therefrom across the surface [(5)] of the support element [(3)].

2.(Amended) A reactor as claimed in claim 1, wherein the axis [(6)] is substantially parallel to a direction of action of terrestrial gravity.

3.(Amended) A reactor as claimed in claim 1, wherein the axis [(6)] is inclined with respect to a direction of action of terrestrial gravity.

4.(Amended) A reactor as claimed in claim 1[ or 3], wherein the axis [(6)] is substantially

perpendicular to a direction of action of terrestrial gravity.

5.(Amended) A reactor as claimed in [any preceding] claim 1, wherein the trough [(13,14)] is centrally located in the region of the axis [(6)].

6.(Amended) A reactor as claimed in [any preceding] claim 1, wherein the trough [(13,14)] is in the form of an annulus.

7.(Amended) A reactor as claimed in [any preceding] claim 1, wherein the trough [(13,14)] is centred about the axis [(6)].

8.(Amended) A reactor as claimed in [any one of] claim[s] 1[ to 6], wherein the trough [(13,14)] is not centred on the axis.

9.(Amended) A reactor as claimed in [any preceding] claim 1, wherein a plurality of troughs [(13,14)] is provided in the surface [(5)].

10.(Amended) A reactor as claimed in claim 9, wherein each trough [(13,14)] has associated with it a feed means [(4)].

11.(Amended) A reactor as claimed in [any preceding] claim 1, wherein the trough [(13,14)] is provided with a matrix which serves to assist reactant [(15)] in the trough [(13,14)] to rotate with the support element [(3)] when this is rotated.

12.(Amended) A reactor as claimed in claim 11, wherein the matrix comprises a fibrous mesh.

13. A reactor as claimed in claim 12, wherein the fibrous mesh is made of a metallic material.

14.(Amended) A reactor as claimed in claim 12[ or 13], wherein the fibrous mesh includes a catalytic material.

15.(Amended) A reactor as claimed in [any preceding] claim 1, wherein the collector means includes a receptacle [(7)] in the form of a bowl or trough at least partially surrounding the support element [(3)].

16.(Amended) A reactor as claimed in [any preceding] claim 1, wherein the collector means includes a deflector positioned about a periphery of the support element [(3)], against which product [(19)] is thrown from an edge region of the surface [(5)] when the support element [(3)] is rotating at an appropriate speed.

17.(Amended) A reactor as claimed in [any preceding] claim\_1, wherein the collector means is coated or otherwise provided with a catalytic material.

18.(Amended) A reactor as claimed in [any preceding] claim\_1, wherein the collector means includes means for heating or cooling product [(19)] in the collector means to a predetermined temperature.

19.(Amended) A reactor as claimed in [any preceding] claim\_1, wherein the collector means is provided with feed means for adding a reactant to product [(19)] collected therein.

20.(Amended) A reactor as claimed in [any preceding] claim\_1, wherein the collector means comprises a wall [(18)] disposed on a periphery of the support element [(3)] and extending from the surface [(5)].

21.(Amended) A reactor as claimed in claim 20, wherein the collector means further comprises a pitot tube [(20)] which extends close to the surface [(5)] in the region of the wall [(18)] and which serves to remove product [(19)] from this region when the support element [(3)] is rotated.

22.(Amended) A reactor as claimed in [any preceding] claim\_1, wherein the collector means is adapted at least partially to recycle collected product [(19)] to the trough [(13,14)] as feed reactant.

23.(Amended) A reactor as claimed in [any preceding] claim\_1, wherein the trough [(13,14)] is coated or otherwise provided with a catalytic material.

24.(Amended) A reactor as claimed in [any preceding] claim\_1, including a plurality of support elements [(3)].

25.(Amended) A reactor as claimed in claim 24, wherein the plurality of support elements [(3)] is mounted on a single axis of rotation [(6)].

26.(Amended) A reactor as claimed in claim 24, wherein the plurality of support elements [(3)] is mounted on a plurality of axes of rotation [(6)].

27.(Amended) A reactor as claimed in [any one of] claim[s] 24[ to 26], wherein product [(19)] collected from a first support member [(3)] is used as feed for a second support member [(3)].

28.(Amended) A reactor as claimed in [any one of] claims 24[ to 26], wherein feed means [(4)] connected in parallel are used to supply reactant [(15)] to each support element [(3)] and in which collector means [(20)] connected in parallel are used to collect product [(19)] from each

support element [(3)].

29.(Amended) A reactor as claimed in claim 27, wherein a processing unit [(22)] is provided between the collector means [(21)] of the first support member [(3)] and the feed means [(4)] of the second support member [(3)].

30.(Amended) A reactor as claimed in claim 29, wherein the processing unit [(22)] is a pump, an extruder, a heater or a heat exchanger.

31.(Amended) A reactor as claimed in [any preceding] claim\_1, wherein the feed means [(4)] includes means for applying electromagnetic radiation or energy to the reactant [(15)].

32.(Amended) A reactor as claimed in [any preceding] claim\_1, further including means for applying vibration to the support member [(3)].

33.(Amended) A reactor as claimed in [any preceding] claim\_1, wherein there is further provided a rotary impeller or fan [(70)] mounted close to the surface [(5)] and operable to generate a gaseous flow from a periphery of the surface [(5)] towards a central region thereof, this flow being counter-current to a flow of reactant [(15)] on the surface [(5)].

**ROTATING SURFACE OF REVOLUTION REACTOR WITH FEED AND  
COLLECTION MECHANISMS**

The present invention relates to a rotating surface of revolution reactor provided with  
various feed and collection mechanisms for input and output products.

The invention makes use of rotating surfaces of revolution technology (hereinafter  
RSORT) (commonly known as spinning disc technology).

- 10 The spinning disc concept is an attempt to apply process intensification methods  
within the fields of heat and mass transfer. The technology operates by the use of  
high gravity fields created by rotation of a disc surface causing fluid introduced to the  
disc surface at its axis to flow radially outward under the influence of centrifugal  
acceleration in the form of thin often wavy films. Such thin films have been shown  
15 to significantly improve the heat and mass transfer rates and mixing. The technology  
was developed for typical heat and mass transfer operations such as heat exchanging,  
heating, cooling and mixing, blending and the like, for example as disclosed in R J J  
Jachuck and C Ramshaw, "Process Intensification: Heat transfer characteristics of  
tailored rotating surfaces", Heat Recovery Systems & CHP, Vol. 14, No 5, p475-491,  
20 1994.

More recently the technology has been adapted for use as a reacting surface for  
systems which are heat and mass transfer limited, for example for the reaction of  
substrates which are highly viscous during at least a stage of the reaction and cause  
problems in achieving good mixing and product yields.

Boodhoo, Jachuck & Ramshaw disclose in "Process Intensification: Spinning Disc  
Polymeriser for the Manufacture of Polystyrene" the use of a spinning disc apparatus  
in which monomer and initiator is reacted by conventional means to provide a pre-  
polymer which is then passed across the surface of a spinning disc at elevated  
30 temperature providing a conversion product in the form of polymerised styrene.

EP 0 499 363 (Tioxide Group Services Limited) discloses another use for spinning  
disc technology in photo catalytic degradation of organic materials such a  
hydrocarbons. A solution of salicylic acid and titanium dioxide catalyst was passed  
35 across the surface of a rotating disc and irradiated with ultra violet light.

These publications therefore disclose the use of spinning disc technology for heating and mass transfer in inert and reactive systems.

5 GB 9903474.6 (University of Newcastle), from which the present application claims priority and the disclosure of which is hereby incorporated into the present application by reference, describes the use of RSORT in the conversion of a fluid phase substrate by dynamic heterogeneous contact with an agent. In this application, it is described how it has surprisingly been found that spinning disc technology may be further adapted to apply process intensification methods not only within the fields  
10 of heat and mass transfer but also within the field of heterogeneous contacting. Furthermore, it is described how it has surprisingly been found that the quality of the product obtained is of higher quality than that obtained by conventional processing having, for example, a higher purity or, in polymers, a narrower molecular distribution.

15 In addition to this, spinning disc technology can be used to obtain products not readily obtainable by other technology.

20 According to the present invention, there is provided a reactor apparatus including a support element adapted to be rotatable about an axis, the support element having a surface, feed means for supplying at least one reactant to the surface of the support element and collector means for collecting product from the surface of the support element, characterised in that the surface includes an undercut trough into which the  
25 at least one reactant is directly supplied by the feed means when the reactor apparatus is in use, and in that, upon rotation of the support element, the at least one reactant forms a generally annular film within the at least one undercut trough and passes therefrom across the surface of the support element.

30 It is to be understood that the term "reactant" is not limited to substances which are intended to undergo chemical reaction on the surface of the support element, but also includes substances which are intended to undergo physical or other processes such as mixing or heating. Similarly, the term "product" is intended to denote the substance or substances which are collected from the surface of the support element, whether these have undergone chemical or physical processing or both. In addition,  
35 although it is envisaged that most reactants and products will be in the liquid phase, the apparatus can be used with any suitable fluid phase reactants and products, including combinations of liquid, solid and gaseous reactants and products. For example, solid phase substances in substantially free-flowing particulate form can have macroscopic fluid flow properties.

- The depth of the trough may be selected in accordance with reaction requirements. For example, for photochemical reactions in which UV light is shone onto the reactant, it is preferred for the trough to be relatively shallow, for example having a 5 depth of the same order of magnitude or within one order of magnitude as the expected thickness of a film of reactant formed across the surface of the support element when rotating at an appropriate speed.
- An RSORT apparatus (commonly known as a spinning disc reactor) generally 10 includes within a conversion chamber a rotating surface or an assembly of a plurality of these which is rotated about an axis to effect transfer of one or more reactants from the axis preferably radially across the rotating surface.
- An RSORT apparatus as hereinbefore defined comprising a rotating surface as 15 hereinbefore defined has a number of advantageous constructional features according to the present invention.
- The axis of rotation of the rotating surface or support member may be substantially vertical, in which case gravity tends to pull reactants downwardly with respect to the 20 surface or support member. This may be advantageous with less viscous reactants. Alternatively, the axis of rotation may be generally horizontal, which can achieve improved mixing of reactants provided that these are appropriately retained on the surface of the support member.
- Any suitable feed means may be provided to feed the at least one reactant onto the 25 rotating surface. For example, the feed means may comprise a feed distributor in the form of a "shower head", a "necklace" of outlets or a simple, preferably adjustable, single point introduction such as a "hose-pipe type" feed means. Preferably, the feed means comprises a feed distributor having a plurality of uniformly spaced outlets for 30 the at least one reactant onto the rotating surface as hereinbefore defined. The feed means may also include means for applying UV, IR, X-ray, RF, microwave or other types of electromagnetic radiation or energy, including magnetic and electric fields, to the reactants as they are fed to the trough, or may include means for applying vibration, such as ultrasonic vibration, or heat.
- 35 The feed means may be provided at any suitable position with respect to the rotating surface which allows feed of the reactant. For example, the feed means may be

axially aligned with the rotating surface for axial feed. Alternatively, the feed means may be positioned such that the feed is spaced from the axis of the rotating surface. Such a position may lead to more turbulence and an enhanced mixing effect.

- 5 In one embodiment, feed means may comprise a single feed to the trough which is preferably situated on or co-axial with the axis of rotation of the rotating surface. In this embodiment, reactant flows from the feed outlet into the trough and is subsequently spread out of the trough on to the rotating surface by centrifugal force. In a preferred embodiment, the rotating element as hereinbefore defined comprises a trough situated on the axis of rotation.
- 10

The trough as hereinbefore defined may be of any suitable shape such as continuous or annular. For example it may have a continuous concave surface comprising part of a sphere, such as a hemispherical surface, or it may have an inner surface joined to the rotating surface by at least one connection wall or at least two, in the case where the trough is annular. The inner surface and connection wall may be of any form

15 which allows the function of a trough to be fulfilled. For example the inner surface may be parallel to the rotating surface or concave or convex. The connection wall may comprise a single circular or ovoid wall or a plurality of straight walls. The walls may diverge or converge towards the rotating surface.

20

25 Preferably, a single circular wall is provided which converges towards the rotating surface to form an undercut trough. This shape generates a reservoir which enhances a circumferential distribution of the reactant flow. Alternative means for forming an undercut trough are also envisaged. For example, where the trough is generally annular in shape, an outer wall may be provided as above, and an inner wall having any suitable shape may serve to define an inner edge to the trough. The undercut portion of the trough should generally be provided as an outer wall so as to help prevent uncontrolled egress of reactant from the trough to the surface under the influence of centrifugal force as the support element is rotated.

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35 Advantageously, a matrix may be provided in the trough so as to help reactant present in the trough to rotate with the support element, thereby helping to achieve substantially uniform flow from the trough across the surface. The matrix may be in the form of a plug of fibrous mesh, such as metal or plastics wool, or may take the form of a plurality of projections which are secured to an inner surface of the trough.

Other matrix means will be apparent to the skilled reader. In some

- embodiments, the matrix is manufactured of a material which is inert with respect to the at least one reactant or the product and which is not significantly affected by temperature and other variable process conditions. Alternatively, the matrix may be made of a material which does interact with the at least one reactant or the product,
- 5 such as a heterogeneous catalyst (e.g. nickel, palladium or platinum or any suitable metal or alloy or compound thereof). Where the matrix is made out of an electrically conductive material, it may be possible to supply an electric current therethrough and thus to provide heating means for heating the at least one reactant within the trough.
- 10 In a further embodiment, there may be provided a plurality of feeds adapted selectively to supply one or more reactants to a plurality of troughs formed in the surface. For example, where the support element is generally disc-like and has a substantially central axis of rotation, there may be provided a first central trough centred on the axis of rotation and feed means for supplying at least one reactant to the first trough, and at least one further trough, preferably also centred on the axis of rotation and having an annular configuration, the at least one further trough being provided with feed means for supplying a second reactant, which may be the same as or different from the first reactant, to the at least one further trough. It will be apparent to the skilled reader that a plurality of troughs may be provided in a similar manner on support elements with shapes other than generally disc-like.
- 15 By providing a plurality of troughs and feeds, a sequence of reactions can be performed across the surface of the support element. For example, two reactants may be supplied to the first trough in which some mixing and reaction will take place. As the support element rotates, the reactants will spread from the first trough to the surface of the support element, where further reaction and mixing takes place, and thence into a second annular trough concentric with the first trough. A third reactant may then be supplied to the second trough, and further mixing and reaction will take place as the third reactant and the two initial reactants and any associated product are spread from the second trough onto the surface of the support element for further mixing and reaction. Because the direction of travel of the reactants and products is outwards from the axis of rotation, a controlled series of reactions can be carried out across the surface of the support member.
- 20
- 25
- 30
- 35 In some embodiments, one of the reactants may be a liquid phase component and another may be a gaseous phase component. In these embodiment, the rotating support member is advantageously contained within a vessel so as to allow the

- concentration of the gaseous phase component in the vicinity of the surface to be controlled. The liquid component may be fed to the surface of the disc as described above, and the gaseous component supplied to the vessel. A rotary impeller or fan or similar device may be mounted close to the rotating surface and driven so as to suck the gaseous phase component from a region surrounding the periphery of the rotating surface towards the centre of the rotating surface while the liquid phase component travels from the centre of the surface towards its periphery due to the rotation of the rotating surface. Where, for example, the support element is a disc, the impeller or fan may take the form of a generally disc shaped structure mounted coaxially with the support element and close thereto. A surface of the impeller or fan facing the rotating surface of the support element may be provided with blades or vanes such that rotation of the impeller or fan serves to suck the gaseous phase component from a periphery of the surface and the impeller or fan towards the centre of the surface. By providing a counter-current flow of the gaseous and liquid phase components, heat or mass transfer between the components is much improved, since the concentration of unreacted liquid phase reactant is lowest at the periphery of the disc, and therefore benefits from a high concentration of the gaseous phase component so as to ensure full reaction.
- Any suitable collection means may be provided for collection of the product as it leaves the rotating surface at its periphery. For example, there may be provided a receptacle in the form of a bowl or trough at least partially surrounding the rotating element or other fixed part of the apparatus. The collection means may additionally comprise a deflector positioned around the periphery of the rotating surface to deflect product into the collection means. The deflector is preferably positioned at an acute angle to the rotating surface.

The components of the collection means, such as the bowl or trough or deflector, may be coated or otherwise provided with a heterogeneous catalyst appropriate to the reactants being reacted on the support element, or may even consist entirely of a material which acts as a heterogeneous catalyst. Furthermore, the components of the collection means may be heated or cooled to a predetermined temperature so as to enable control over reaction parameters, for example by serving to halt the reaction between reactants as these leave the surface in the form of product. Feed means for supplying a reactant to the product leaving the surface may also be provided. For example, there may be provided feed means for feeding a quenching medium to product in the collection means so as to halt chemical or other reactions between

reactants when these have left the surface.

The collection means may further comprise outlet means of any suitable form. For example, there may be a single collection trough running around the periphery of the disc or a collection bowl partially surrounding the rotating element.

5 Outlet means may also be provided in the collection means and these may take the form of apertures of any size and form situated at any suitable position of the collection means to allow egress of the product. In one preferred embodiment, the  
10 outlet means are situated to allow vertical egress of the substrate in use.

Alternatively, the collection means may comprise an outer wall provided at the periphery of the support element so as to prevent product from being thrown from the surface, and at least one pitot tube which extends into the product which is restrained  
15 at the periphery of the support element by the outer wall. The outer wall may converge generally towards the axis of rotation of the support member so as better to retain product while the support element is undergoing rotation, although other wall configurations, such as generally parallel to or divergent from the axis of rotation may also be useful.

20 Embodiments of the present invention may include multiple support elements, which may share a common axis of rotation and which may be mounted on a single rotatable shaft, or which may be provided with individual rotatable shafts. The collection means associated with any given support element may be connected to the  
25 feed means associated with any other given support element so as to link a number of support elements in series or parallel. In this way, a reaction may be conducted across a number of support elements in series or parallel. The collection means of a first support member may be directly connected to the feed means of a second support member, or may be connected by way of a processing unit such as a pump,  
30 extruder, heater or heat exchanger or any other appropriate device. This is especially useful when dealing with viscous products, such as those which are obtained in polymerisation reactions, since the viscous product of a first support element may be processed so as to acquire more favourable physical characteristics before being used as the reactant feed for a second support element.

35 For example, where the collection means comprises an outer wall on the surface of the support element as described above, a number of support elements may be

coaxially mounted on a single rotatable shaft so as to form a stack of support elements. A reactant feed is led to the trough of a first support element, and a collector in the form of a pitot tube has its tip located near the surface of the first support element in the vicinity of the wall so as to take up product from this region.

- 5 An end of the pitot tube remote from the tip is led to the trough of a second support element so as to allow the product of the first support element to serve as the reactant for the second support element, thereby allowing a number of reactions to take place in series. Alternatively, a number of parallel feeds may supply the same at least one reactant simultaneously to the troughs of a number of support elements and a number 10 of parallel pitot tube collectors may gather product from a peripheral region of each support element, thereby allowing a reaction to take place across a number of support elements in parallel.

- 15 It is also envisaged that product collected from the periphery of a support element may be recycled as feed for that support element. This is useful for processes requiring an extended contact time for the reactants. The product may be fully or only partially recycled, depending on requirements.

- 20 Reference herein to a rotating surface is to any continuous or discrete planar or three dimensional surface or assembly which rotates approximately or truly about an axis, and preferably is reference to an approximate or true rotating surface of revolution. An approximate rotating surface of revolution may comprise an asymmetric axis and/or deviation in the surface body and/or circumference creating an axially or radially undulating surface of revolution. A discrete surface may be in the form of a 25 mesh, grid, corrugated surface and the like.

- 30 Reference herein to a substantially radially outward flowing film as hereinbefore defined is to any fluid film which may be created by dynamic contact of the fluid phase reactant and the rotating surface as hereinbefore defined, suitably the fluid phase reactant is contacted with the rotating surface at any one or more surface locations and caused to flow outwardly by the action of centrifugal force. A film may be a continuous annulus or may be a non-continuous arc at any radial location. The substrate may provide a plurality of films in dynamic contact with a rotating surface as hereinbefore defined.

- 35 For example processes requiring extended contact time may be carried out in continuous manner with use of a recycle of fluid exiting at the periphery of the

rotating surface towards the axis of the rotating surface enabling sequential passes of fluid across the surface. In continuous steady state operation an amount of fluid exiting the surface may be drawn off as product and an amount may be returned by recycle for further conversion with an amount of fresh reactant feed.

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The process of the invention as hereinbefore defined may operate in a single or plural stages. A plural stage process may comprise a first pre-process stage with further post-process or upgrading stages, and may be carried out batchwise with use of a single rotating surface as hereinbefore defined or may be carried out in 10 continuous manner with multiple rotating surfaces in series.

Second or more reactants may be added to the feed reactant as it passes from one rotating assembly to the next or be added directly to the rotating assembly anywhere between the axis of rotation or the exit from the assembly. In certain cases a multi-step process may be achieved by reactant addition or additions between the axis of 15 rotation and the exit of a single rotating assembly to achieve more than one process step in a single pass. It is also possible to have different regions of the rotating surface at different temperatures and conditions and have different surface geometries as appropriate to the process needs.

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It will be apparent that the process of the invention may be controlled both by selection of a specific rotating surface for the support element and by selecting process variables such as temperature, speed of rotation, rate of reactant feed, conversion time and the like. Accordingly the process of the invention provides 25 enhanced flexibility in process control including both conventional control by means of operating conditions, and additionally control by means of rotating surface type.

The apparatus may further comprise any suitable control system. Such a control system may regulate the temperature or contact time of reactants by means of speed 30 of rotation, rate of substrate feed and other process parameters to obtain an optimum result.

The apparatus as hereinbefore defined may comprise means for optimising process conditions. For example, means for imparting an additional movement to the 35 rotating surface, and thus to the reactant, may be provided. Such movement could be in any desired plane or plurality of planes and preferably comprises vibration. Any suitable vibration means may be provided, such as flexible mounting of the surface or

off centre mounting, both inducing passive vibration or active vibration means, such as a mechanical element in contact with the rotating element and vibrating in a direction parallel to the rotating element axis. Preferably a passive vibration means is provided in the form of off centre mounting of the rotating element on its axis of rotation. Vibration may alternatively be provided by an ultrasonic emitter in contact with the rotating element for vibration in any desired plane or plurality of planes.

The rotating surface may have any shape and surface formation to optimise process conditions. For example the rotating surface may be generally planar or curved, frilled, corrugated or bent. The rotating surface may form a cone or be of generally frustoconical shape.

In one preferred embodiment the rotating surface is generally planar and preferably generally circular. The periphery of the rotating surface may form an oval, rectangle or other shape.

In another preferred embodiment the rotating surface is provided as the inner surface of a cone. The apparatus may comprise at least one cone and at least one other rotating surface or at least one pair of facing cones positioned so as to allow a two stage process with one or more reactants fed to each cone. Preferably product exits a smaller cone (or other surface of rotation) in a spray on to the surface of a larger cone (or other surface of rotation) by which it is at least partially surrounded and for the surface of which a further reactant is fed by feed means as hereinbefore defined, to allow mix of the product and reactant on the larger rotating surface. Preferably, means are provided such that the two cones counter rotate. Such an arrangement enhances mixing and intimate contact of the reactants and reduces the required physical contact time. Alternatively, means are provided such that the cones co-rotate or one is stationary.

In another embodiment, there may be provided two generally planar support elements mounted coaxially and generally parallel to each other on an axis of rotation. The facing surfaces of the support elements may be provided with at least one generally circular wall defined about the axis of rotation, and preferably a plurality of concentric walls, the walls being divergent with respect to the axis of rotation of their respective support element. The walls on one support element are positioned out of phase with the walls on the other support element so that the walls fit between each other when the support elements are brought close together. Reactant may be

supplied to a region within the innermost wall on one of the support elements. Upon rotation of the support elements, the reactant will tend to move along an interior surface of the divergent wall towards a region within the next wall on the opposed support element, and thence onto an interior surface of the said next wall back towards the first support element. The reactant may continue to move back and forth between the support members so as to progress in a zig-zag manner in a generally radial direction away from the axis of rotation along the interior surfaces of the intermeshed walls towards an outer collection point as described above. In this way, a compact reactor with a high surface area is achieved, the surface consisting of the 5 interior surfaces of all the concentric walls. The support elements may rotate together in a given direction, or may rotate at different speeds in the same direction, or may rotate at the same speed or at different speeds in opposed directions.

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15 A rotating surface of any shape and surface formation as hereinbefore defined may be provided with surface features which serve to promote the desired process. For example, the surface may be micro or macro profiled, micro or macro porous, non stick, for example may have a release coating, may be continuous or discontinuous and may comprise elements such as mesh, for example woven mesh, reticulate foam, pellets, cloth, pins or wires, for enhanced surface area, enhanced or reduced friction 20 effect, enhanced or reduced laminar flow, shear mixing of recirculation flow in axial direction and the like.

25 In one preferred embodiment, mixing characteristics of the rotating surface are enhanced by the above features or the like provided on or in the rotating surface. These may be provided in any suitable regular or random arrangement of grids, concentric rings, spider web or like patterns which may be suitable for a given application.

30 Alternatively or additionally to any other surface feature, radially spaced pins in the form of circles or segments of circles may be provided.

In another preferred embodiment, a porous surface coating is provided, which aids processing of certain reactants. Such a coating may be provided in combination with any other of the aforementioned surface features.

35 Surface features in the form of grooves may be concentric or may be of any desired

radially spaced form. For example, the grooves may form "wavy" or distorted circles for maximised mixing.

5 Grooves may be parallel sided, or may have one or both sides which diverge to form undercut grooves or which converge to form tapered grooves. Preferably, the grooves are undercut to promote mixing.

Grooves may be angled to project towards or away from the axis of the rotating surface to enhance or reduce undercut or taper.

10

Energy transfer means may be provided for the rotating surface or reactant or product as hereinbefore described. For example heating means may be provided to heat the reactant, for example, as part of the feed means. Additionally, or alternatively heating means may be provided to heat the rotating element in the form of radiant or other heaters positioned on the face of the rotating element which does not comprise the rotating surface for conversion. Preferably, radially spaced, generally circular radiant heaters are provided.

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Any preferred cooling or quenching means may be provided in a suitable position to cool the reacted substrate. For example cooling coils or a heat sink may provide cooling by heat exchange, or a reservoir of quench may provide cooling or reaction termination by intimate mixing in the collection means.

20

For a better understanding of the present invention and to show how it may be carried into effect, reference shall now be made by way of example to the accompanying drawings, in which:

FIGURE 1 shows a spinning disc apparatus in schematic form;

30 FIGURE 2 shows a detail of a spinning disc having a central trough;

FIGURE 3 shows a detail of a spinning disc having an annular trough;

35 FIGURE 4 shows a number of spinning discs in schematic form and operatively arranged in series;

FIGURE 5 shows a number of spinning discs in schematic form and operatively

arranged in parallel;

FIGURE 6 shows two coaxial spinning discs in schematic form and provided with a pump unit for transferring product from one disc as feed to the second disc;

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FIGURE 7 shows two rotating support elements with intermeshing concentric circular walls; and

FIGURE 8 shows a spinning disc provided with a rotary impeller.

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Figure 1 illustrates a spinning disc apparatus of the present invention. The apparatus is enclosed in vessel (1) having at its axis a drive shaft (2) supporting a spinning disc (3). Feed means (4) provides reactant to an undercut annular trough (13) provided in the surface (5) of the disc (3) about its axis (6). Rotation of the disc (3) causes

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reactant to flow radially outwards, whereby it contacts the surface (5) of the spinning disc (3). Fluid is collected at the peripheral edges of the disc (3) by means of collection trough (7) and may be rapidly quenched by means of cooling coils (8). A skirt (9) prevents meniscal draw back of fluid contaminating the drive shaft mechanism. Inlet means (10) enable controlled environment conditions to the

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provided, for example a nitrogen atmosphere. Outlet vent means (11) enable the venting of atmospheric gases or gases evolved during operation. Observation means are provided by means of windows (12) to observe the progress of the conversion.

The apparatus of Figure 1 may be started up and operated as described in Example 1  
25 below. In the case that the process is an exothermic conversion, cooling coils (8) may be used to quench the collected product in the trough (7). The spinning disc (3) is provided with heating coils (not shown) which may be used to initiate or maintain conversion. The disc (3) or the reactor vessel (1) may be provided with a source of radiation, means for applying an electric or magnetic field and the like as described,  
30 at or above the disc surface (5) or at the wall of the reactor vessel (1).

In Figure 2 there is shown an axially located central trough (14) which is continuous and forms a well situated on the axis of rotation (6) of the rotating surface (5) of a disc (3). Rotation causes reactant (15) supplied by the feed means (4) to flow to the wall and form an annular film (16) within the trough (14). The annular film (16) then spills over onto the surface (5) of the disc (3) to form a film (17) on the surface (5).

In Figure 3 the trough (13) is annular and forms a channel co-axial about the axis of rotation (6) of the disc (3). Rotation assisted by the trough profile causes reactant (15) to flow into the trough (13) and to the wall thereof and form an annular film (16) within the trough (13) before spilling over onto the surface (5) of the disc (3) in the form of a film (17).

Figure 4 shows three discs (3) coaxially mounted on a drive shaft (2) which defines an axis of rotation (6). Each disc (3) has a central trough (13) into which reactant (15) may be fed, and a peripheral wall (18). Reactant (15) is supplied to the trough (13) of the topmost disc (3) by way of feed means (4), and then spreads out over the surface (5) of the disc (3). Product (19) is collected from the vicinity of the peripheral wall (18) by way of a pitot tube collector (20), which then feeds product (19) to the trough (13) of the next disc (3) down on the drive shaft (2). In this way, a process can be performed across a number of discs (3) in series.

Figure 5 shows three discs (3) coaxially mounted on a drive shaft (2) which defines an axis of rotation (6). Each disc (3) has a central trough (13) into which reactant (15) may be fed, and a peripheral wall (18). Reactant (15) is supplied in parallel to the trough (13) of each disc (3) by way of feed means (4), and then spreads out over the surfaces (5) of the discs (3). Product (19) is collected from the vicinity of the peripheral walls (18) by way of pitot tube collectors (20), which are also connected in parallel. In this way, a process can be performed across a number of discs (3) in parallel

Figure 6 shows two discs (3) coaxially mounted on a drive shaft (2) which defines an axis of rotation (6). Each disc (3) has a central trough (13) into which reactant (15) may be fed by feed means (4) before spilling onto the surface (5) of each disc (3). A collector trough (21) is provided about the periphery of each disc (3) so as to collect product (19) thrown from the discs (3). An outlet from the upper collector trough (21) passes through a pump or extruder (22) before leading to the trough (13) of the lower disc (3) as feed means (4). This arrangement is suitable for use with viscous reactants and products.

Figure 7 shows a pair of planar rotating support elements (80, 81) coaxially mounted on an axis of rotation (6). The facing surfaces (82, 83) of the support elements (80, 81) are each provided with a plurality of concentric circular walls (84, 85, 86, 87),

with walls (84, 86) mounted on surface (82) and walls (85, 87) mounted on surface (83). The walls (84, 85, 86, 87) are divergent with respect to the axis of rotation of their respective support element (80, 81) and are positioned so that they mesh with each other when the support elements (80, 81) are brought together as shown.

- 5 Reactant (15) is supplied to an interior region of wall (84) near surface (82) by a feed (4), and then proceeds to travel along an interior surface of wall (84) towards surface (83). When the reactant (15) reaches the top of wall (84), it spills over onto an interior surface of wall (85) on support element (81) and travels back towards support element (80) as shown. This process is repeated until the reactant (15) is thrown  
10 from the top of the outermost wall (87) into collecting means (not shown). By providing a convoluted surface along which the reactant (15) may travel, a very compact reactor may be obtained. The support elements (80, 81) may co- or counter-rotate, either at the same or at different rotational speeds.
- 15 Figure 8 shows a spinning disc (3) with a surface (5) mounted on a drive shaft (2) inside a vessel (1) and provided with a feed (4) for a liquid phase reactant, such as an organic prepolymer. A rotary impeller (70) is mounted coaxially with the disc (3) and close to the surface (5), and a surface (71) of the impeller (70) facing the surface (5) is provided with vanes (72). A gaseous phase reactant, such as nitrogen, is supplied to the vessel (1) through an inlet (10). Upon rotation of the disc (3), the liquid phase reactant moves from the centre of the surface (5) towards the periphery thereof as described above. When the impeller (70) is appropriately rotated on a drive shaft (74), the gaseous phase reactant is sucked into the space (73) between the impeller (70) and the surface (5) and moves towards the centre of the surface (5)  
20 against the flow of liquid phase reactant, thereby improving mass and/or heat transfer characteristics. Gaseous phase reactant and unwanted reaction by-products may be removed from the central region of the space (73) by way of a discharge pipe (75) to which at least a partial vacuum may be applied. A partial seal (76) in the discharge pipe (75) may be provided so as to control the rate of gaseous phase reactant and by-  
25 product removal.  
30

**Example 1 – Polymerisation of ethylene using a catalyst coated disc**

Phillips catalyst was coated onto the surface of a spinning disc apparatus using methods as described hereinbefore. The coated disc was mounted in a spinning disc apparatus.

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The spinning disc apparatus used is shown in diagrammatic form in Figure 1. The main components of interest being:

- i) Top Disc – A smooth brass disc of thickness 17mm and diameter 500mm capable of rotating around a vertical axis.
- 10 ii) Liquid Distributor – A circular copper pipe of diameter 100mm, positioned concentrically over the disc, sprayed fluid vertically onto the disc surface from 50 uniformly spaced holes in the underside. Flowrate was controlled manually by a valve and monitored using a metric 18 size, stainless steel float rotameter. A typical fluid flow rate was 31.3cc/s.
- 15 iii) Motor – A variable speed d.c. motor capable of rotating at 3000 rpm was used. The rotational speed was varied using a digital controller calibrated for disc speeds between 0 and 1000 rpm. A typical rotational speed was 50rpm.
- iv) Radiant Heaters – 3 radiant heaters (each consisting of two elements) spaced equally below the disc provided heat to the disc. The temperature was varied using a temperature controller for each heater. Each heater temperature could be controlled up to 400°C. Triac regulators were used to control the speed of the controller response. (These remained on setting 10 throughout the tests).
- 25 v) Thermocouples and Datascaner – 16 K-type thermocouples embedded in the top disc gave an indication of the surface temperature profile along the disc radius. Odd numbered thermocouples 1 to 15 inclusive were embedded from underneath the disc to a distance 3mm from the upper disc surface. Even numbered thermocouples, 2 to 16 inclusive were embedded from underneath the disc to a distance 10mm from the upper disc surface. Each pair of thermocouple, i.e. 1 & 2 and 3 & 4 and 5 & 6 etc., were embedded adjacently at radial distances of 85mm, 95mm, 110mm, 128mm, 150mm, 175mm, 205mm and 245mm respectively (see Figure 3). The thermocouples were connected to the datascaner which transmitted and logged the data to the PC at set intervals using the DALITE Configuration and Monitoring

Software Package.

vi) Manual Thermocouple – A hand-held K-type thermocouple was used to measure the bulk fluid temperature on top of the disc.

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The rig was used in two arrangements. In one arrangement, feed was constantly added and the heated product was sent to the collection trough. In an alternative arrangement the rig was assembled with a recycle.

10 The spinning disc apparatus of Figure 1 was started up and temperature and rotational speed adjusted. When steady stage was achieved gaseous ethylene was fed to the revolving catalyst coated disc surface at it axis. Product was withdrawn in the collection trough at the periphery of the disc. Analysis revealed the product was high grade polyethylene.

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Further advantages of the invention are apparent from the foregoing.

CLAIMS:

1. A reactor apparatus including a support element (3) adapted to be rotatable about an axis (6), the support element (3) having a surface (5), feed means (4) for supplying at least one reactant (15) to the surface (5) of the support element (3) and collector means for collecting product (19) from the surface (5) of the support element (3), characterised in that the surface (5) includes an undercut trough (13,14) into which the at least one reactant (15) is directly supplied by the feed means (4) when the reactor apparatus is in use, and in that, upon rotation of the support element (3), the at least one reactant (15) forms a generally annular film (16) within the at least one undercut trough (13,14) and passes therefrom across the surface (5) of the support element (3).
2. A reactor as claimed in claim 1, wherein the axis (6) is substantially parallel to a direction of action of terrestrial gravity.
3. A reactor as claimed in claim 1, wherein the axis (6) is inclined with respect to a direction of action of terrestrial gravity.
- 20 4. A reactor as claimed in claim 1 or 3, wherein the axis (6) is substantially perpendicular to a direction of action of terrestrial gravity.
5. A reactor as claimed in any preceding claim, wherein the trough (13,14) is centrally located in the region of the axis (6).
- 25 6. A reactor as claimed in any preceding claim, wherein the trough (13,14) is in the form of an annulus.
7. A reactor as claimed in any preceding claim, wherein the trough (13,14) is centred about the axis (6).
- 30 8. A reactor as claimed in any one of claims 1 to 6, wherein the trough (13,14) is not centred on the axis.
- 35 9. A reactor as claimed in any preceding claim, wherein a plurality of troughs (13,14) is provided in the surface (5).

with it a feed means (4).

11. A reactor as claimed in any preceding claim, wherein the trough (13,14) is provided with a matrix which serves to assist reactant (15) in the trough (13,14) to rotate with the support element (3) when this is rotated.  
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12. A reactor as claimed in claim 11, wherein the matrix comprises a fibrous mesh.
- 10 13. A reactor as claimed in claim 12, wherein the fibrous mesh is made of a metallic material.
14. A reactor as claimed in claim 12 or 13, wherein the fibrous mesh includes a catalytic material.  
15
15. A reactor as claimed in any preceding claim, wherein the collector means includes a receptacle (7) in the form of a bowl or trough at least partially surrounding the support element (3).
- 20 16. A reactor as claimed in any preceding claim, wherein the collector means includes a deflector positioned about a periphery of the support element (3), against which product (19) is thrown from an edge region of the surface (5) when the support element (3) is rotating at an appropriate speed.
- 25 17. A reactor as claimed in any preceding claim, wherein the collector means is coated or otherwise provided with a catalytic material.
18. A reactor as claimed in any preceding claim, wherein the collector means includes means for heating or cooling product (19) in the collector means to a predetermined temperature.  
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19. A reactor as claimed in any preceding claim, wherein the collector means is provided with feed means for adding a reactant to product (19) collected therein.
- 35 20. A reactor as claimed in any preceding claim, wherein the collector means comprises a wall (18) disposed on a periphery of the support element (3) and extending from the surface (5).

21. A reactor as claimed in claim 20, wherein the collector means further comprises a pitot tube (20) which extends close to the surface (5) in the region of the wall (18) and which serves to remove product (19) from this region when the support element (3) is rotated.
- 10 22. A reactor as claimed in any preceding claim, wherein the collector means is adapted at least partially to recycle collected product (19) to the trough (13,14) as feed reactant.
23. A reactor as claimed in any preceding claim, wherein the trough (13,14) is coated or otherwise provided with a catalytic material.
- 15 24. A reactor as claimed in any preceding claim, including a plurality of support elements (3).
25. A reactor as claimed in claim 24, wherein the plurality of support elements (3) is mounted on a single axis of rotation (6).
- 20 26. A reactor as claimed in claim 24, wherein the plurality of support elements (3) is mounted on a plurality of axes of rotation (6).
- 25 27. A reactor as claimed in any one of claims 24 to 26, wherein product (19) collected from a first support member (3) is used as feed for a second support member (3).
- 30 28. A reactor as claimed in any one of claims 24 to 26, wherein feed means (4) connected in parallel are used to supply reactant (15) to each support element (3) and in which collector means (20) connected in parallel are used to collect product (19) from each support element (3).
- 35 29. A reactor as claimed in claim 27, wherein a processing unit (22) is provided between the collector means (21) of the first support member (3) and the feed means (4) of the second support member (3).
30. A reactor as claimed in claim 29, wherein the processing unit (22) is a pump, an extruder, a heater or a heat exchanger.

31. A reactor as claimed in any preceding claim, wherein the feed means (4) includes means for applying electromagnetic radiation or energy to the reactant (15).
- 5 32. A reactor as claimed in any preceding claim, further including means for applying vibration to the support member (3).
33. A reactor as claimed in any preceding claim, wherein there is further provided a rotary impeller or fan (70) mounted close to the surface (5) and operable to generate 10 a gaseous flow from a periphery of the surface (5) towards a central region thereof, this flow being counter-current to a flow of reactant (15) on the surface (5).

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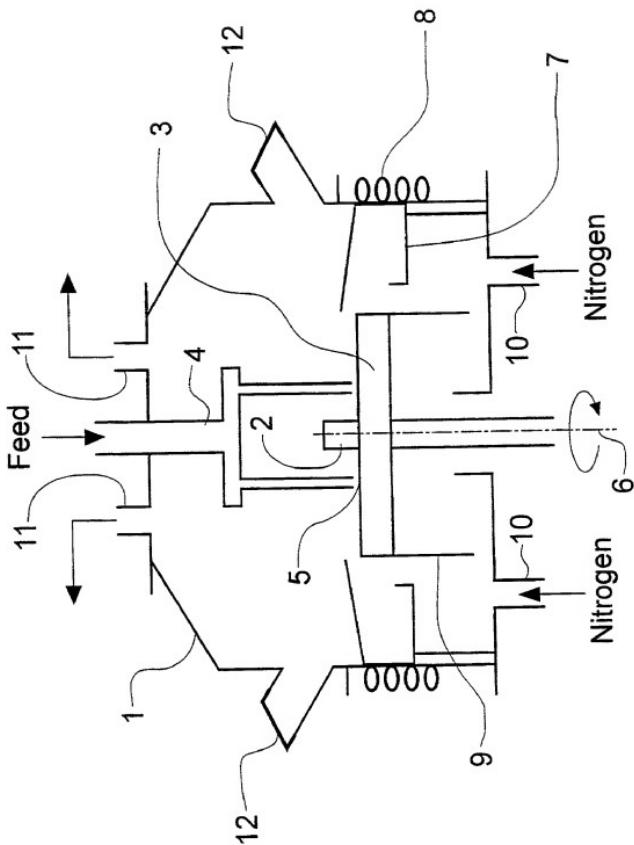


Fig. 1

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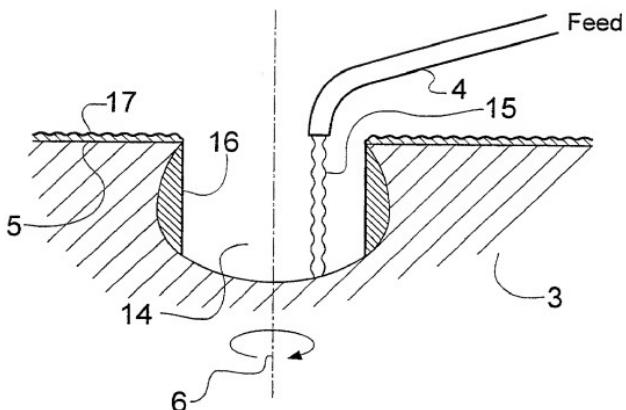


Fig. 2

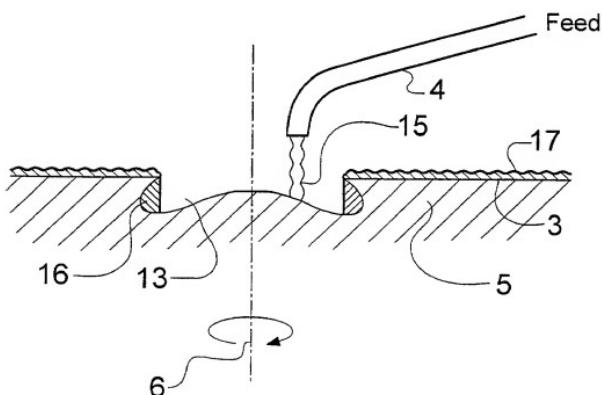


Fig. 3

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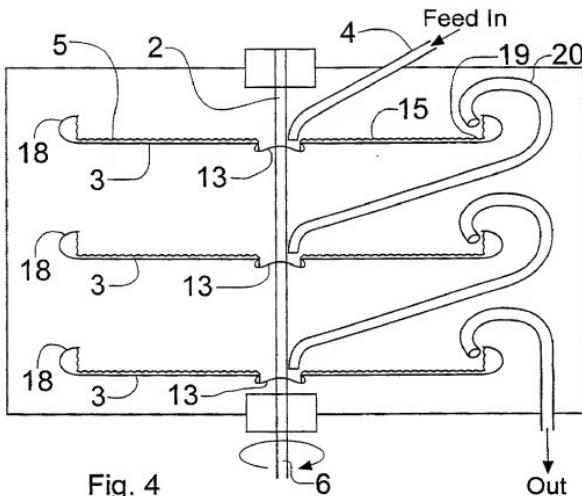


Fig. 4

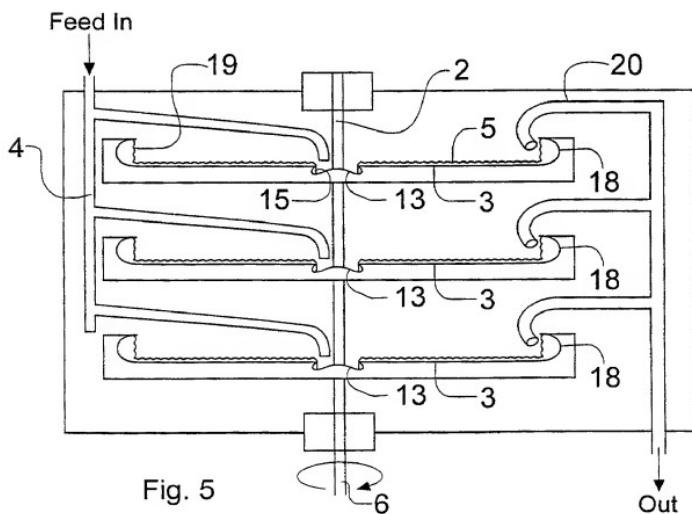
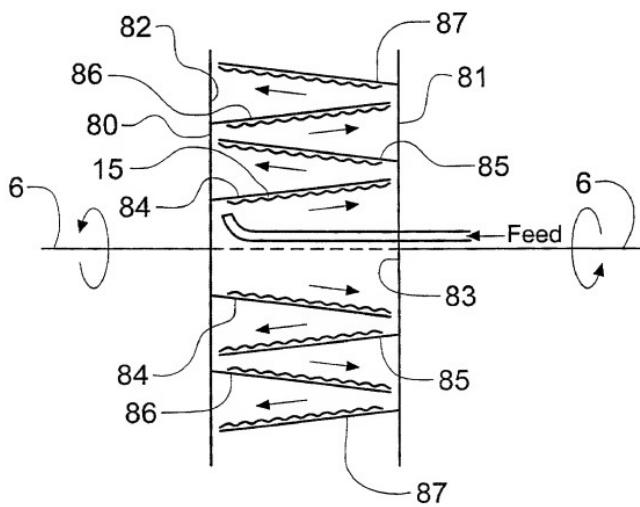
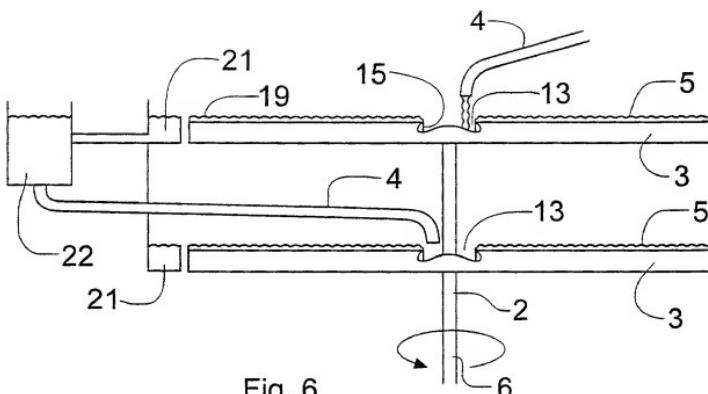


Fig. 5

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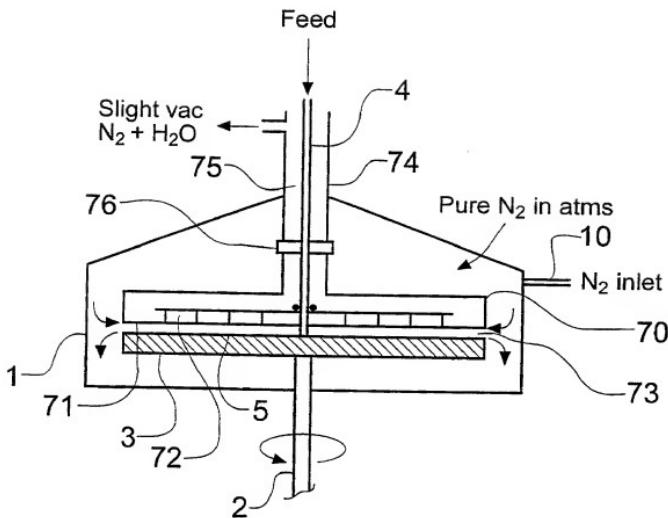


Fig. 8



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**DECLARATION FOR UTILITY OR  
DESIGN  
PATENT APPLICATION  
(37 CFR 1.63)**

Declaration Submitted with Initial Filing

OR

Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	A01204US (98148.18)
First Named Inventor	RAMSHAW, Colin
<b>COMPLETE IF KNOWN</b>	
Application Number	09 / 913,902
Filing Date	02/17/2000
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, mailing address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**ROTATING SURFACE OF REVOLUTION REACTOR WITH FEED AND  
COLLECTION MECHANISMS**

*(Title of the Invention)*

the specification of which

is attached hereto

OR

was filed on (MM/DD/YYYY) **02/17/2000** as United States Application Number or PCT International

Application Number **PCT/GB00/00521** and was amended on (MM/DD/YYYY) **03/20/2001** (if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b) of any foreign application(s) for patent, inventor's or plant breeder's rights certificate(s), or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below by checking the box, any foreign application for patent, inventor's or plant breeder's rights certificate(s), or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	Certified Copy Attached? NO
9903474.6	GB	02/17/1999	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>

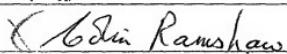
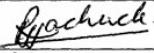
Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

[Page 1 of 2]

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**DECLARATION — Utility or Design Patent Application**

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.				
NAME OF SOLE OR FIRST INVENTOR: <input type="checkbox"/> A petition has been filed for this unsigned inventor				
Given Name (first and middle [if any]) <u>Colin</u>		Family Name or Surname <u>RAMSHAW</u>		
Inventor's Signature 			Date <u>23rd November 2001</u>	
Residence: City <u>Ponteland</u>	State <u>C.I.B.X</u>	UK Country	UK Citizenship	
Mailing Address <u>20 High View, Ponteland, Newcastle upon Tyne NE20 9ET</u>				
City _____	State _____	ZIP _____	Country <u>UK</u>	
NAME OF SECOND INVENTOR: <input type="checkbox"/> A petition has been filed for this unsigned inventor				
Given Name (first and middle [if any]) <u>Roshan Jeet Jee</u>		Family Name or Surname <u>JACHUCK</u>		
Inventor's Signature 			Date <u>23rd November 2001</u>	
Residence: City <u>Abbey Farm</u>	State <u>C.I.B.X</u>	UK Country	Indian Citizenship	
Mailing Address <u>10 Marcross Close, North Walbottle, Newcastle upon Tyne NE 1 7RU</u>				
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<input type="checkbox"/> Additional inventors are being named on the _____ supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto				